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bilitari truncum aortæ, et ad aneurysmata reddi pronum. Demonstrat etiam, in ipso sanguine ubique terram veram calculosam circumvehi, nec in renalibus solum viis deponi, sed ibi hæere et congeri, ubi ruptæ sunt levissimæ membranæ vasorum, et attractio terrearum molecularum ad asperas inæquales superficies major est.

XVI. *A Memoir on the Lacrymæ Batavicæ, or Glass-Drops, the tempering of Steel, and Effervescence, accounted for by the same Principle. By Claud, Nic. le Cat, M. D. F. R. S. &c. Translated from the French, by T. S. M. D.*

Read June 15. 1749. **T**HE Glass-Tear, or Drop, commonly called *Lacryma Batavica*, or *Lacryma Borussica*, because it was first made in these Countries, is much celebrated among Natural Philosophers, upon account of the singular Phenomena which it exhibits, and which have for a long Time exercised their Sagacity.

The Make of this Drop is as simple as its Explanation is difficult. It is the Work of the meanest Workman in a Glass-house. On the Top of an iron Rod they take up a small Quantity of the Matter of Glass in Fusion: They let it drop into a Pail of Water: The Drop makes that Part of the Water which it touches, to boil with a hissing Noise, as a red-hot Iron would do, which it resembles in that Instant; and when it does not break in this Operation,

ration, as it most frequently does, it forms the little pyramidal Mass, which is known by the Name of a Glass-Drop; the Effects whereof I will first relate, and then endeavour to account for them.

Experiment 1. This Drop is of such Hardness and Resistance, that it bears smart Blows of a Hammer, without breaking.

Exper. 2. Nevertheless, if you grind the Surface of this Drop which resisted the Hammer, or if you only break the Tip of the small End or Tail, the Whole shatters into Powder.

Exper. 3. This Shattering of the Drops is attended with a loud Report; and the Dust or Powder to which it is reduced, shoots out, and scatters all around.

Exper. 4. If the Drop be ground with Powder of Emery, imbibed with Oil, it often escapes breaking.

Exper. 5. If this Experiment be made in the Air-Pump, the Drop bursts with greater Impetuosity, so as sometimes to break the Receiver; and its Dust is finer than when done in the open Air; and if it be made in the dark, the Drop in bursting produces a little Light.

Exper. 6. If this Drop be annealed in the Fire, it loses all these Singularities; and being reduced to the State of common Glass, it easily breaks under

der the Hammer; and does not burſt upon breaking the ſmall End.

Exper. 7. The Drops that are made by letting them cool in the Air, produce no other Effects than thoſe which have been annealed.

The firſt natural Philoſophers who endeavoured to inveſtigate the Cauſe of theſe Phænomena, imagined that they found it in the Air. Some of them ſuppoſed, that this Air was ſhut up in the Drop by the Cruſt which the cold Water forms on its Surface while it is yet red-hot; and attributed its Rupture to the Violence with which this Air iſſued thro' the too narrow Paſſage made for it, in breaking the ſmall End of the Drop. Others maintained on the contrary, that the Drop, in this State, contained no Air at all, nor any thing but Particles of Fire, or ſubtile Matter; or, in one Word, a Vacuum of Air; and that the ſudden burſting of the Drop was occaſioned by the impetuous Entry of the Air into this ſort of Vacuum. In fine, the *Carteſians* have ſubſtituted their ſubtile Matter in the room of this exterior Air, and ſay, that the Drop is burſted by the leſs ſubtile Particles of this Matter; which entering with Force into the Drop by the Opening made therein, and finding large Pores on the Inſide, and ſmall ones on the Outſide, burſt the Sides of the Drop, by ruſhing from the Centre to the Circumference, wherewith its Paſſage is obſtructed.

Meſſ. *Mariotte* and *Homburg* came afterwards; Being provided with an Air Pump, they cauſed one of theſe Drops to be broken *in Vacuo*; and *Homburg*

berg having observed, that it broke therein better and with a louder Report than in the open Air; they both inferred, that neither the impetuous Entry of the outward Air, nor that of a Fluid somewhat less gross, could be the Cause of this Shock; because the Receiver of the Air-Pump is void of these Fluids; and even if a little should remain therein, it is too much rarefied, and too thin to be capable of such an Effect.

Mr. *Mariotte*, thro' some Remains of Attachment to an Opinion, which he had held to that Time, did not intirely exclude the exterior Air from the Cause of the Phenomenon of the Drop; but thought proper to add another to it; which he makes use of as a Substitute in Cases like those of the preceding Experiment, where the Insufficiency of the Air, or of a Fluid nearly similar to it, plainly appears.

Mr. *Homburg* shews no Indulgence to the exterior Fluid; and ascribes the Whole to the new Cause, which is, the Quality of temper'd Glass, which the Drop acquires, like Steel, by being thrown red-hot into cold Water. This Tempering, according to these great Academicians, confers at the same time more Springiness to the Parts, and less Connection with each other. When a Steel Sword-Blade is bent forcibly, it breaks more easily than one of Iron; and the Jarring which is occasioned by its Spring, is capable of breaking the other Parts of the Blade: And thus we see, that it generally breaks into several Pieces. This Blade is the Image of the *Lacryma Batavica*, or Glass-Drop.

This is the Point to which I found Things brought, when I began to study the Phenomena of the Glass-Drop.

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The Air was partly banished from the Inside of this Mass of Glass: There is none in the liquid red-hot Matter of a Glass Furnace. It was purely out of Complaisance for a generally received Opinion, that Mr. *Mariotte* allowed the exterior Fluid any Share in the Phænomenon; and Mr. *Homburg* put the finishing hand to its Exclusion. But the Sort of Temper given to the Drop by plunging it red-hot into cold Water, and its Comparison with temper'd Steel, is not so much a Cause as a Comparison: And moreover, is this Comparison very just? Can there be any between a long, thin Sword-Blade, which breaks into two or three Pieces, and a thick inflexible Mass of Glass, which flies into Powder. The Tail alone of the Drop might seem to favour this Parallel: But an Experiment, which I made, entirely destroys this Opinion, and proves, that it is not the Spring, or the Vibrations of the Parts of the Drop, that occasion its bursting.

I put about half the Tail of a Glass Drop into a Vice between two Bits of Deal-board of about a Finger's Breadth. I screw'd the Vice, till I saw this small Cylinder or Thread of Glass make Impressions in the Wood on each Side for its Lodgment, in order to be sure that it could not be susceptible of Vibrations. In this Condition I broke the End of the Tail, supporting it on my Nail, to prevent forcing any Part but the End which I intended to break; and in order to be the more certain of giving no Shock to the Part that was squeezed in the Vice. My Drop flew into Powder as usual; and the Portion secured between the two Bits of Wood, perfectly retained its Figure in the Impressions wherein

it was lodged. But when I touch'd this little Cylinder, it was reduced to Powder, much in the same manner as is said to have happen'd to some Men who had been struck with Lightning. Now, it was not possible for this Glass to receive, or convey to the Body of the Drop any Vibrations; or if any, they must be infinitely small; and yet the Effect was precisely the same as usual. Therefore the System of Vibrations is not happier than those invented before it.

It is among the Glass-workers, and in their Art, that the Secret of the *Lacryma Batavica*, or Glass-Drop, is to be sought; and there it is that I think I have discover'd it.

All those who have seen Glass-houses know, that when a Piece fails in the Hands of a Workman, he throws it aside; and this Piece is not long exposed to the Air, before it breaks in Pieces: And when the same Workman has succeeded in making a Piece, and is willing to preserve it, he takes great Care not to let it cool in the Air; but carries it hot into another Oven of a moderate Heat, where he leaves it for a certain Space of Time. And this last Operation is called *Annealing the Glass*.

A natural Philosopher, who is Witness to this Management, ought to inquire into the Reasons and Necessity of it.

How comes it that the Glass, which cools in the Air, breaks; and when it has been nealed, it does not break? This is the Reason, if I am not mistaken.

A Bit of melted Glass, red-hot and liquid at the same time, is in that State, purely because its Particles are divided by so great a Quantity of Particles
of

of Fire, or subtil Matter so violently agitated, that these component Parts of the Glas do hardly touch one another: They swim, if I may be allowed the Expression, in a Flood of this Matter of Fire; and for this Reason it is, that melted Glas affects the Colours of Flame.

When this Substance is exposed to the Air, the Coolness of this Fluid, which touches the Surface of the Glas, cools that Surface first; that is, brings the Particles nearer together, braces their Pores, and thus imprisons the Particles of Fire, which still fill the Inside of this Substance. While these fiery Particles find Pores enough on the Surface, to move freely, the Glas continues whole; but when the Glas grows colder, that is, when the Pores of its Surface begin to confine these fiery Particles; then their whole Action is exerted against the Parts of the Glas, which they break into a thousand Pieces. In order to avoid this *Fracas*, nothing more is requisite than to keep the Pores on the Surface of the Glas wide enough, that the fiery Particles contain'd therein may pass through, and fly off insensibly. Now, this is what is done, by putting the hot Piece of Glas into an Oven, the moderate Heat of which keeps these Pores open to a certain Pitch, and yet allows the Glas to acquire its due Consistence in this State of middling Porosity: Wherein consists the Annealing of Glas and other fused Substances.

Hence it appears, that all unnealed Glas carries within itself its Principle of Destruction, which is the Matter of Fire imprisoned. But the *Lachryma Batavica*, or Glas-Drop is in this respect, in a worse Case still than unnealed Glas: For besides that it has not been exposed to this secondary Heat, which

which keeps its Pores open, till the Glass has acquired its due Consistence, for Fear that the Coolness of the Air alone should not close its Pores soon enough, and imprison a sufficient Quantity of the igneous Matter, it is suddenly thrown into cold Water, which by its Coldness and Weight is fitter than the Air to produce such an Effect speedily and effectually. Wherefore the only surprising Circumstance in these Glass-Drops is, that any of them remain without breaking, by the great Quantity of igneous Matter suddenly shut up in them by the cold Water. And indeed this Accident befalls more than one half of them; and those that escape, doubtless owe their Preservation to the spherical or cylindrical Figure of the compact Shell, which the Coldness of the Water forms on their Surface: For it is well known that this Figure produces an Equality of Resistance on all Sides, which considerably encreases the resisting Force: And this is the first Reason why, as soon as this *Æquilibrium* is broken, either by rubbing away one Side of this Surface, or by making a Hole in it, or, in fine, by breaking the small End of the Drop; the Resistance is instantly overcome, and the igneous Matter, imprisoned within the Glass, and constantly upon the Strain against it, bursts it into Powder.

This destroyed *Æquilibrium* is but one Disposition that favours the Effect of the imprison'd igneous Matter: But the Communication which is opened for it with the subtile exterior Fluids, rouses this Matter which is in a State of Inactivity, develops its Spring, kindles it somewhat in the Manner of the Phosphorus, which produces no Effect while close shut

shut up, but takes Fire, as soon as a free Communication with the outward Air is given it.

On the Union of these Causes depend the Phenomena of the Glass-Drop. It is of a Hardness that resists the Strokes of a Hammer, because the violent Condensation, given to its Surface by the cold Water, into which it was thrown when in a soft State, render'd its Texture very close, compact, and consequently hard.

It bursts with great Noise; and in so doing it retains the Character of all the Effects produced by the Explosion of the igneous Matter.

Its Dust flies two or three Feet all around, because it is push'd forward by the Action of a Fluid contained in its Centre; which would not happen, if it had been the Effect of an exterior Fluid. This same Dust of the Glass-Drop darts forward with greater Force in the Air-Pump than in the Air, because the Air is an Obstacle, of which it is freed in the Receiver of the Air-Pump: Wherefore it sometimes breaks the Receiver; and for the same Reason its Dust is finer, that is, more minutely broken, as being done by a stronger Power, and less counter-balanced.

This violent Explosion produces Light, because the Property of shining Lightning is always the Effect of such an Explosion of the Matter of Fire: Wherefore this Fact affords another Proof, that this Matter is the Principle of the Phenomenon of the Drop.

If the Surface of the Drop be ground with fine Powder of Emery, imbibed with Oil, it frequently happens, that it does not burst; because the Sort of oily Mastic that results from this Mixture, stops the
Pores

Pores of the Drop, and prevents the sudden Communication of the exterior Fluids with the imprisoned igneous Matter ; and as Glafs cannot be ground with very fine Emery and Oil, but by long rubbing ; such rubbing heats the Drop, and gradually opens the Pores so as to grant an insensible Passage to the igneous Matter, whereby the Drop becomes at last in the same Case with nealed Glafs ; and in the Case in which itself is, when it is put into the Oven to be nealed.

When a Glafs-Drop is made, by suspending it in the Air only, it does not break sooner than nealed Glafs : Because as this small Mass of Glafs retains its Heat a long while in the Air, the Heat serves as a Nealing-Oven, and keeps its Pores dilated long enough for the igneous Particles to find a free Passage.

The Principles, by which I have accounted for the Effects of the Glafs-Drop, are not confined to this Phænomenon alone : They are more general than is commonly imagined. Some Corollaries, which I shall deduce from them, will prove what I advance.

The Tempering of Steel.

Steel, like the Glafs-Drop, acquires its Hardness by being plunged into Water : And if Mess. *Mariotte* and *Homborg* had compared them together in this Circumstance alone, they had been in the right.

The most celebrated natural Philosophers, in order to account for the tempering of Steel, have had recourse to different Arrangements of its Parts produced by the Fire, and fixed, by the Cold of the Water, in the new State, in which the violent Heat had put them.

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The Mechanism of the tempering of Glass Drops, applied to that of Steel, is the most simple of all the Hypotheses, and answers all its Properties, which are these :

1. Tempered Steel has a coarser Grain. 2. Is increased in Bulk. 3. It is harder and brittler. 4. By annealing it becomes less brittle.

Explanation. Steel made red-hot is filled and swelled, and its Pores dilated, by the igneous Matter. In this State, the cold Water, into which it is thrown, compresses and closes the Parts of the Surface, while the imprisoned igneous Matter dilates the Pores within : Thus the Texture of Steel becomes more compact by these two Causes, while its Pores are dilated.

These large Pores constitute the coarse Grain of tempered Steel. Its Dilatation by the igneous Matter, which could not be thoroughly condensed by the Cold of the Water, causes its augmented Bulk : The close Texture of the Substance that surrounds the Pores, and the imprisoned igneous Matter, occasion its Hardness and Brittleness. Its Recoction or Annealing deprives it of this Brittleness, and of a Part of its Hardness : Because it opens this Texture, which it relaxes at the Expence of the neighbouring Pores, and drives the igneous Matter out of it.

Fermentation.

The Fermentation of Acids and Alkali's seem, to be to be another Corollary of the same Principle.

First, It is pretty universally allowed, that the acid Particles have the Figure of small Needles ; and that Alkali's are spheroidal or polyhedrous Bodies with a vast Number of Bodies proper to admit the acid Needles.

Secondly, Experience shews, that Salts are alkalised by Fire, and that our Juices are alkalised by Heat, &c. What can the repeated Action of the Fire produce on Salts, in order to alkalisef them ? It calcines them, blunts their Points, and hollows them with a vast Number of Pores ; and we see with the naked Eye, that Calcination has this Effect on all Bodies. In a word, it converts an angular very solid Body into a very porous and light Spheroid ; and this Body is an Alkali by the first Supposition.

Thirdly, Calcination introduces, and generally leaves in the Pores of the calcined Body, after the Operation, a great Quantity of igneous Matter. This Matter is perceptible to the Senses in the *Lapis Bononiensis*, which becomes a Phosphorus by Calcination ; in Lime-Stone, which by Calcination is furnished with so great a Quantity of igneous Matter, that in the Effervescence, which is raised in it by throwing a little Water on this Stone, you may kindle Sulphur or a Match by it. The Alcaline, or alcalized Salts also, that is, those which are calcined, have their Pores full of the igneous Matter.

Fourthly, Such is the Nature of the igneous Matter, that it tears asunder whatever opposes its Passage,

sage, and makes it fly off with a Report. This Principle is universally allowed: The Effects of Gunpowder, of Volcano's and Earthquakes, prove it: And to come nearer our Subject, unnealed Glass breaks in the Air, and the *Lacryma Batavica* does as much upon breaking its small End.

Whereas an Alkali is a spongy Body filled with the igneous Matter, and an Acid are Points proportioned to these Pores; these ought to be regarded as so many Pegs or Pins, which enter into the Holes on the Surface of the Alkali, and fill them up exactly: Whereby the igneous Matter is imprisoned; and by the preceding Principle it bursts the alkaline Globule with Noise, and scatters around the acid Pegs, in the same manner as it bursts the Glass-Drop.

A Mixture of an alkaline and acid Liquor being composed of an infinite Number of such Particles that burst and broke to Pieces, the Liquor must take up more room, or swell. The Particles of Air therein contained, being tossed about by all those little Explosions, together with the neutral Liquors, which are a Vehicle to the Salts, form the Scum or Froth; and the igneous Matter, which gets out of the Alkali's, and is agitated by the Shocks of all these Explosions, produces Heat, drags with it the aqueous and other volatile Particles, which form the Steam.

Yet there are cold Fermentations, because then, either the Motion of the Particles of Fire, and their *Fracas*, is inconsiderable; or because these Particles fly off easily by a direct Motion. Moreover, at this Day that we have it in our Power to be convinced, that the *Erasp* or Stream of electric Matter is very

cold, nobody will be surpris'd, that a Stream of the Matter of Fire may produce Cold.

If all the alcalious Corpufcles burfted at once, the Fermentation would laft but an Instant : But as the acid Liquor requires a certain Space of Time, to penetrate the whole alkaline Liquor, and fill the Pores of the alcalious Corpufcles, the Fermentation is performed fucceffively in a certain Number of Corpufcles at a time, until they are all broken: And this Succeffion conftitutes the Duration of the Fermentation; which ceafes when there are none of the Alkali's left entire.

Thefe Principles not only ferve to explain the Fermentation which results from the Mixture of Acids and Alkali's, but alfo almoft all the Motions of this Kind, which are occafioned by the Mixture or Penetration of two or more Subftances.

For Example; Lime, which we have mentioned above as a Body filled with the Matter of Fire, and which produces an Effervescence capable of lighting Sulphur, if Water be thrown on it; Lime, I fay, produces this Effect, only becaufe the Particles of Water, which enter into its Pores, have a Tendency to fhut up the igneous Particles more clofely. It is by a Mechanifm entirely fimilar, that *Homborg's* Phosphorus kindles into Flame, upon being expofed to the Air: 'Tis upon this Principle likewise, that a Mixture of Spirit of Wine and Water acquires a new Degree of Heat; and fo of other Phænomena of this Nature.

———— Le Cat.